Modeling of single top tW+b signal at the LHC

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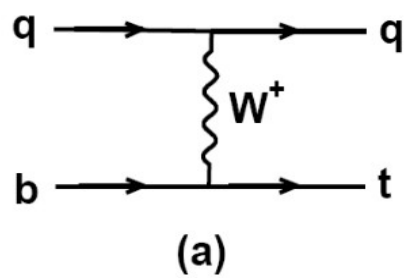
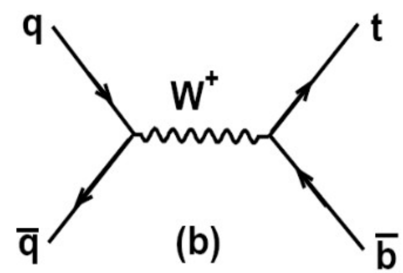
Single top quark production at the LHC:

$$\mathcal{L} = \frac{V_{tb}}{2\sqrt{2}} g_w \left(\bar{b} \gamma^\mu (1-\gamma^5) W_\mu^- t + \bar{t} \gamma^\mu (1-\gamma^5) W_\mu^+ b \right)$$

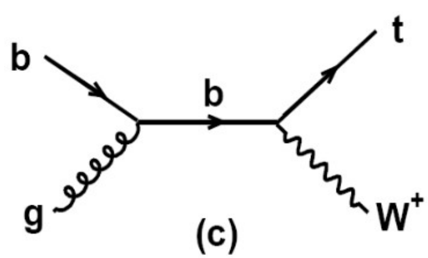
leading order diagrams for single top production

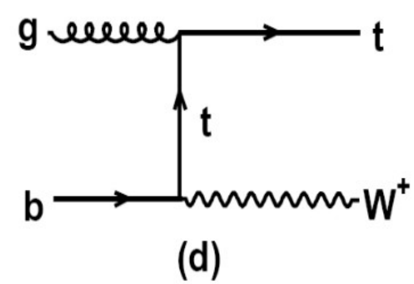


t-channel



s-channel





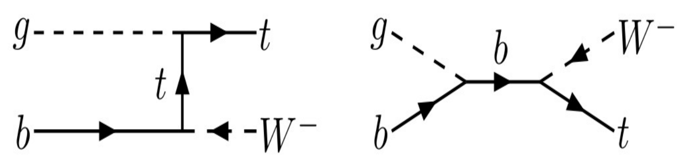
associated tW production

Single Top tWb processes at the LHC:

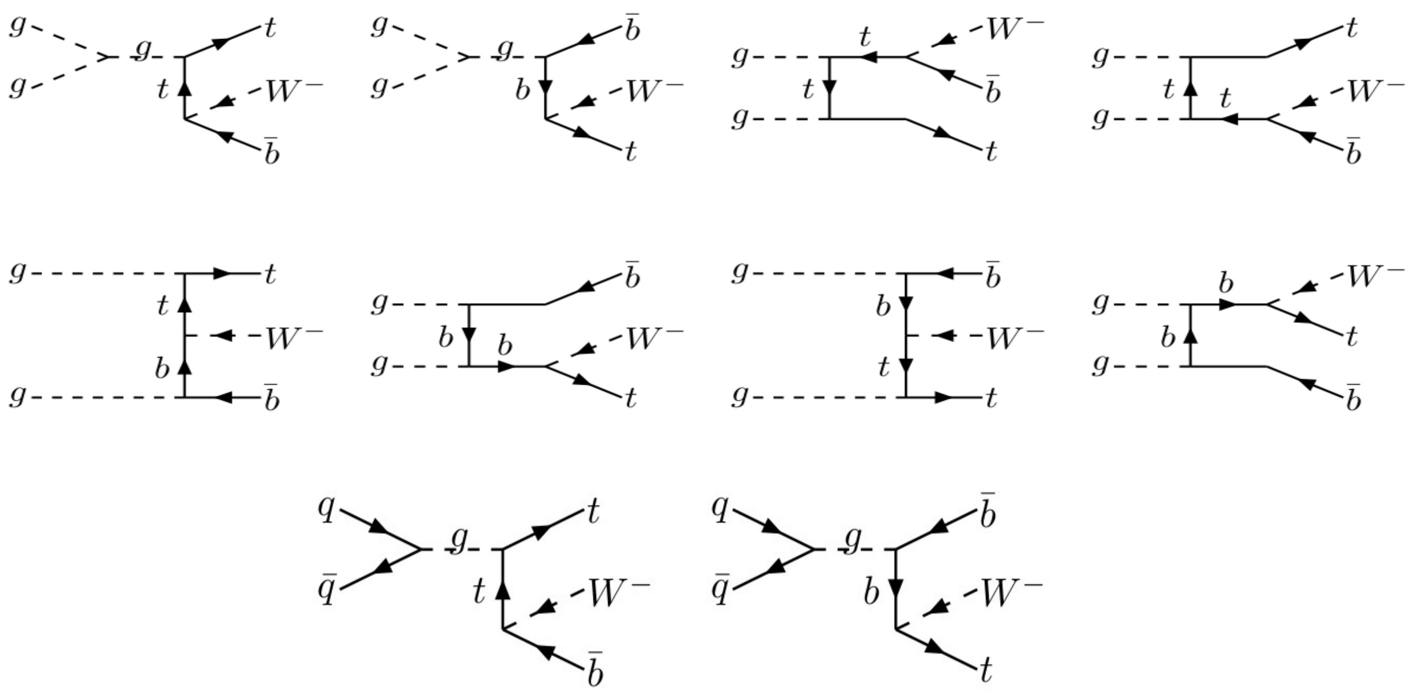
- tWb channel gives a significant contribution to the Single Top signal at the LHC
- SingleTop tWb is one of the main backgrounds for ttbar

Single top quark tWb production at the LHC:

Diagrams for leading order 2 → 2 tW production



O(1/log(mt /mb)) 2 → 3 processes

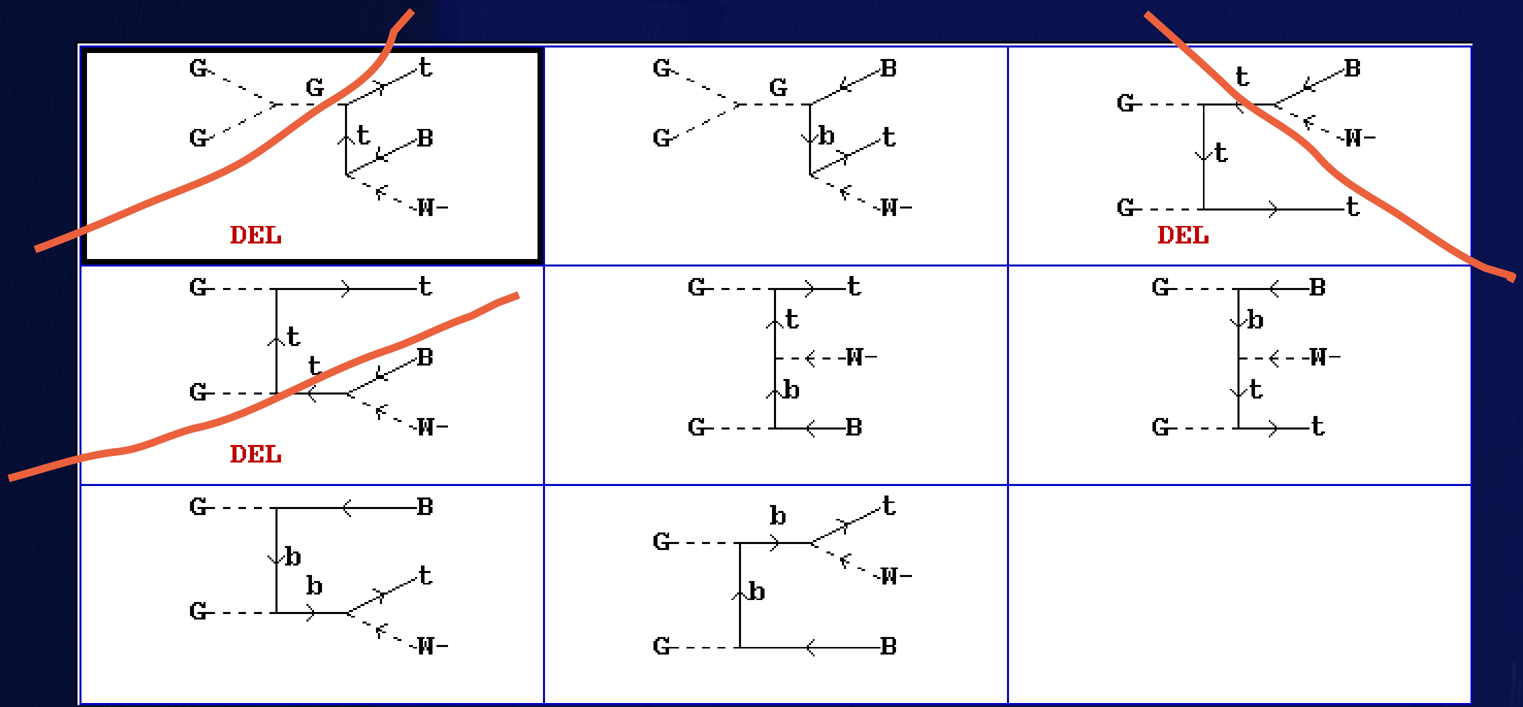


Problems of tWb modeling:

- 1. Discriminate single top tWb and tt-bar events
- 2. Matching 2->2 +ISR and 2->3 events
  (Treatment of the double counting: combining of the Wt+ISR and complete tWb processes)

Methods of discriminating single top tWb and tt-bar

Naive Removing tt-bar resonant diagrams in the tWb amplitude

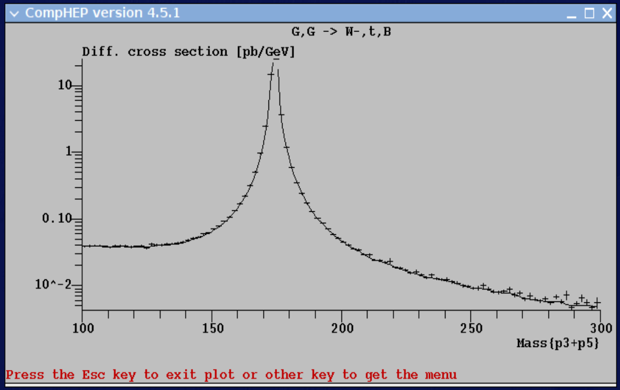


This method IS NOT SUITABLE for real modelling !

- 1. No interference between SingleTop and tt-bar
- 2. Wrong rate
- 3. kinematic distributions are wrong
- 4. Wrong spin correlations

Methods of discriminating single top tWb and tt-bar

tW is distinguished by cuts:



- |M(Wb)-Mt|<kΓt, k=15

  Belayev,Boos,Dudko, hep-ph/9806332
  Tait, hep-ph/9909352
  Used with Comphep (1998)

  Pro: complete spin correlations and interference terms
  Contra: removing some invariant mass region.

- pT(associated b)<65 GeV
  Final state “WWb”, defined by this veto, is called tW

  Campbell, Tramontano, hep-ph/0506289

Methods of discriminating single top tWb and tt-bar

Local cancellation of resonant tt-bar contribution

$$\sigma(gg \to tW\bar{b})_{singletop} = \sigma(gg \to tW\bar{b})_{total} - k^2 \cdot \sigma(gg \to tW\bar{b})_{Narrow\,Width\,Approach}$$

$$k = 0.01 \quad \Gamma_{narrow} = 0.0001 \cdot \Gamma_t$$

In the region where invariant mass of Wb system is close to top quark mass the behaviour of partonic cross section may be expressed as (Tait, hep-ph/9909352):

$$k^2 \cdot \sigma(gg \to tW\bar{b})_{Narrow\,Width\,Approach} = \sigma(gg \to t\bar{t}) \cdot Br(t \to W\bar{b})$$

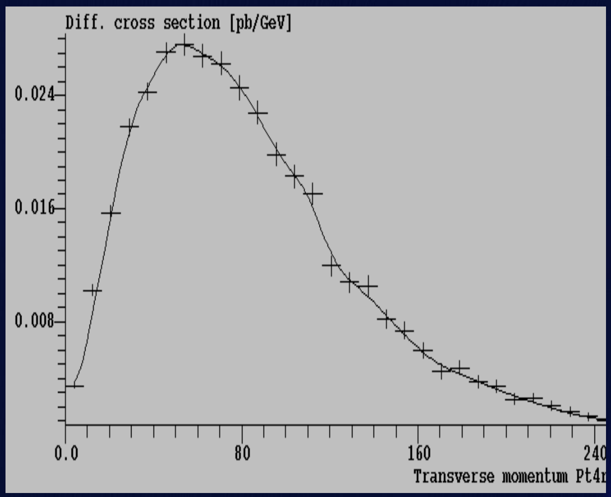
Pro:

- gauge invariant,
- correct total rate,
- correct spin correlation,
- complete set of interference terms,

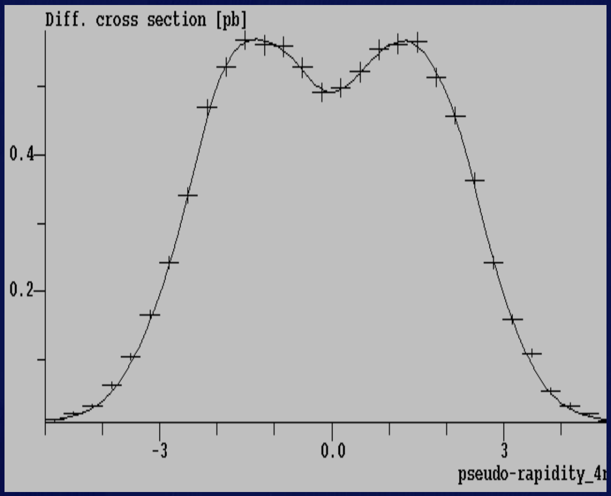
Contra:

- slow speed of calculations
- there are some events with negative weights,

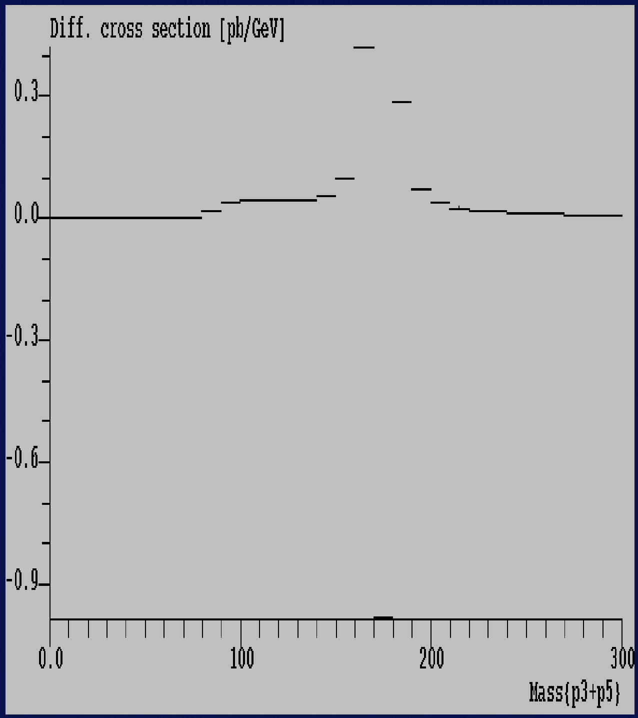
Kinematic distributions after applying local subtraction procedure



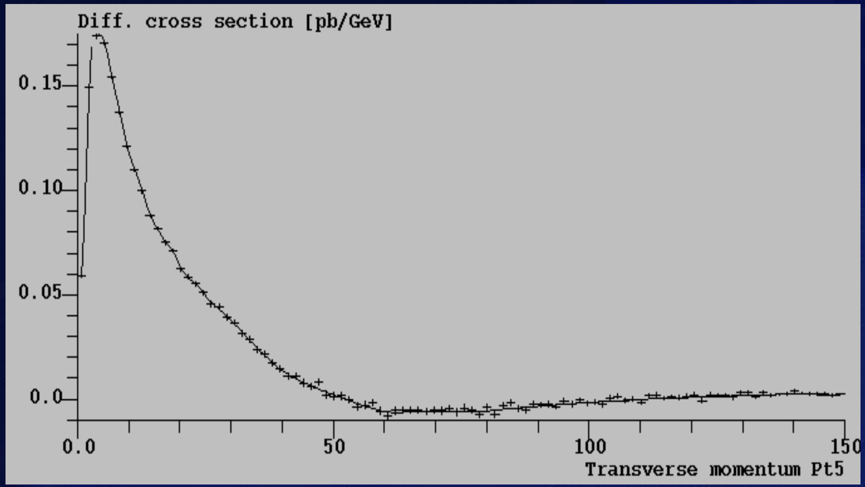
PT of top-quark



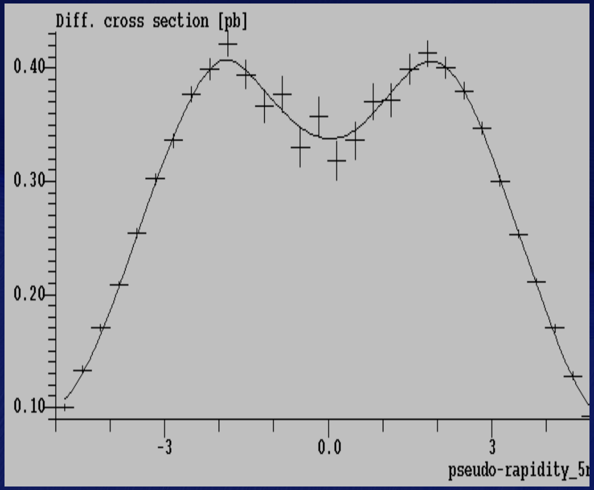
Pseudo-rapidity of top-quark



Wb-invariant mass



PT of b-quark



pseudo-rapidity of b-quark

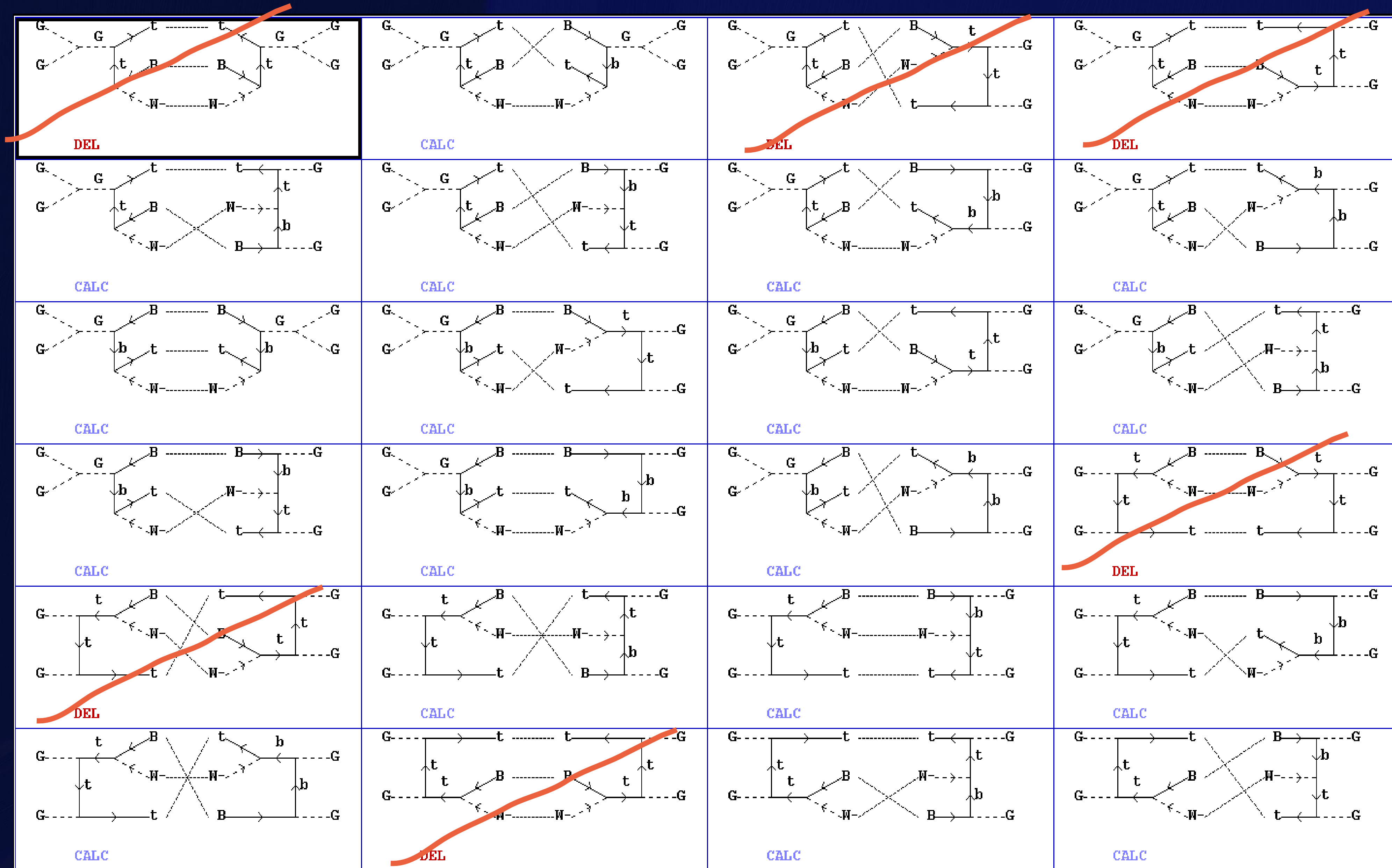
σ = 3.1 pb

Method of “Local cancellation of resonant tt-bar contribution” is good for accurate calculations of cross section,

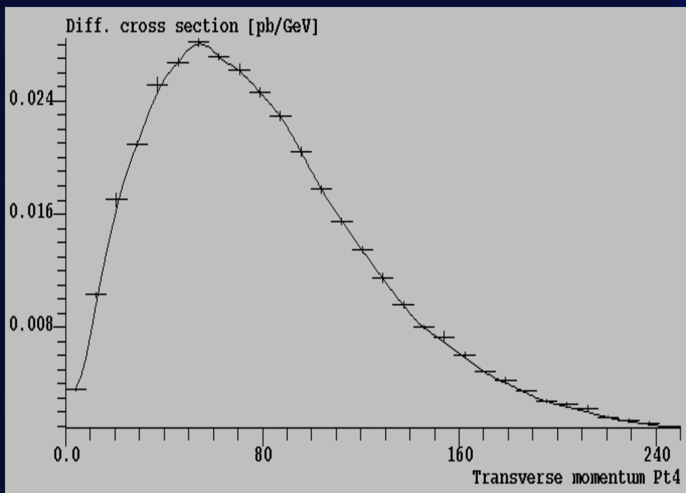
but it leads to events with negative weights, to additional singularities and increases the computation time.

We need a more efficient method for generating MC events

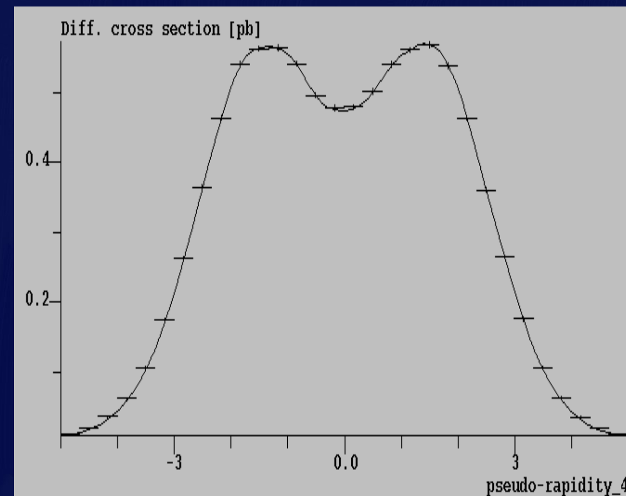
Removing tt-bar resonant squared diagrams in the matrix element



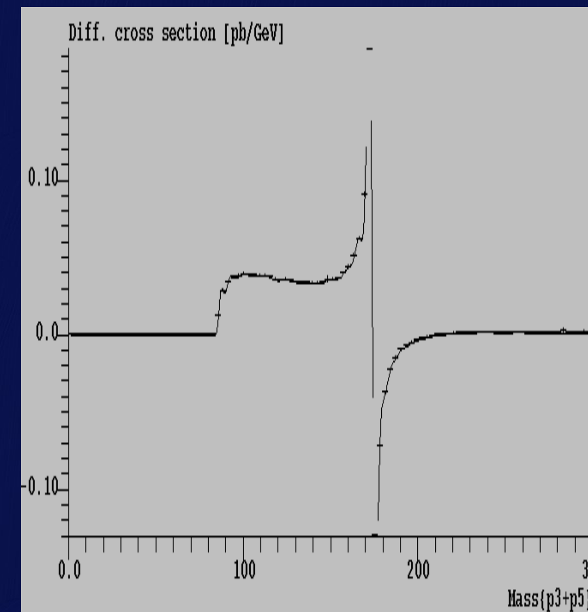
Kinematic distributions after removing tt-bar resonant squared diagrams in the matrix element



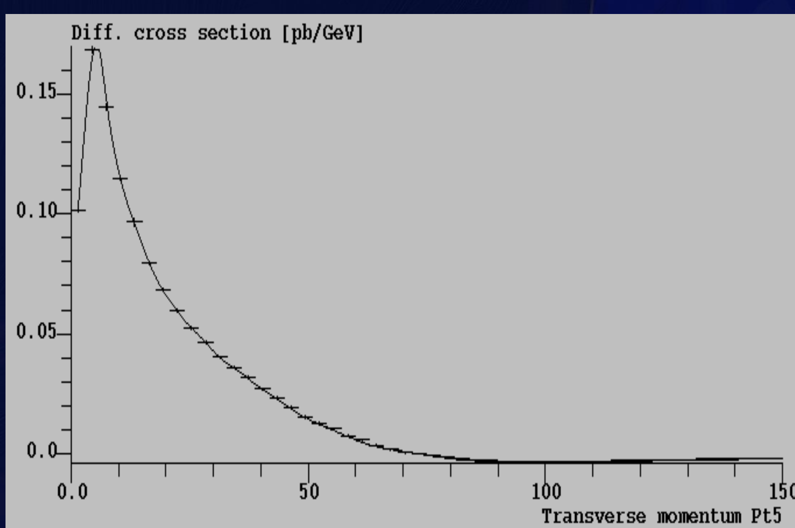
PT of top-quark



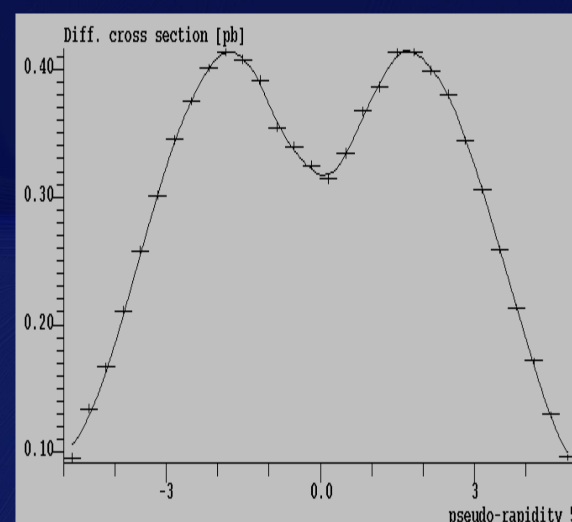
Pseudo-rapidity of top-quark



Wb-invariant mass



PT of b-quark



pseudo-rapidity of b-quark

σ = 3.1 pb

Method of “Removing tt-bar resonant squared diagrams” is rather good,

It keeps interference, spin correlations and correct rate
but it leads to additional singularities.

Method needs some corrections ->

Applying wide width approach procedure to the interference terms after removing tt-bar resonant squared diagrams

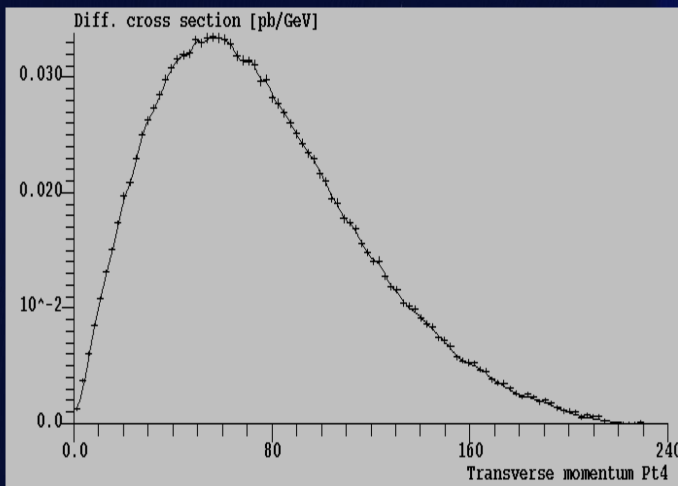
$$\sigma(gg \rightarrow t\,W\,\bar{b})_{SingleTop} = \sigma_{SingleTop\;Resonant} + k^2 \cdot \sigma^{Wide\,Width\;Approach}_{Interference(SingleTop + t\,\bar{t})}$$

$$k = 10 \qquad \Gamma_{wide} = 10000\,GeV$$

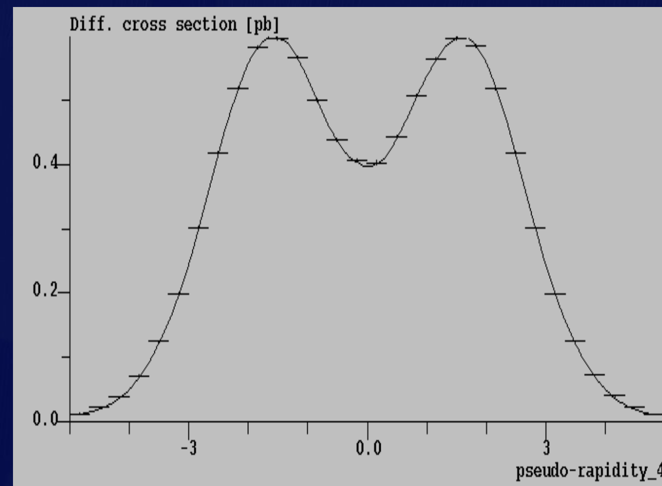
Pro:

- correct total rate,
- correct spin correlation,
- correct kinematic distributions
- complete set of interference terms,
- there are no events with negative weights,
- high speed of calculations,
- straightforward way to produce events beyond SM (with anomalous couplings etc...).

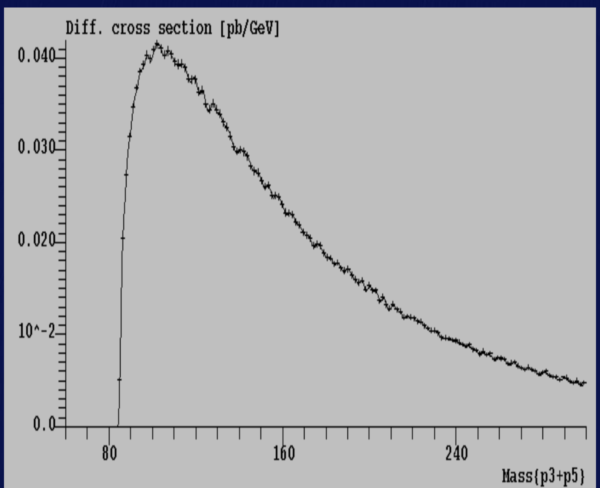
Kinematic distributions after removing tt-bar resonant squared diagrams and applying wide width approach



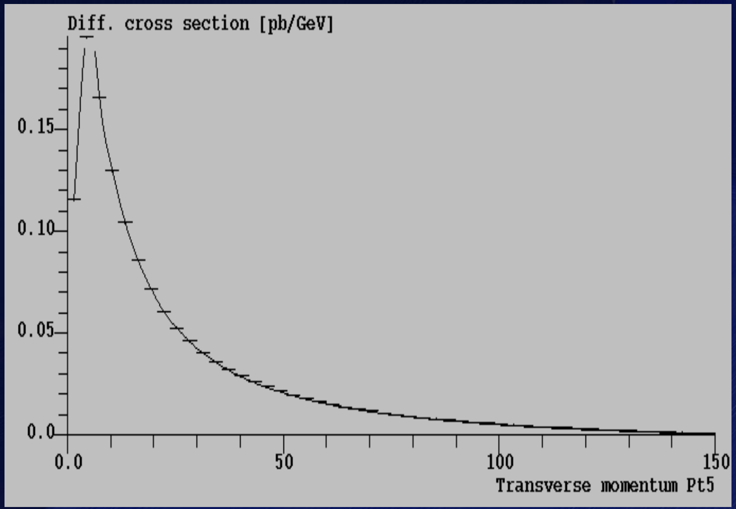
PT of top-quark



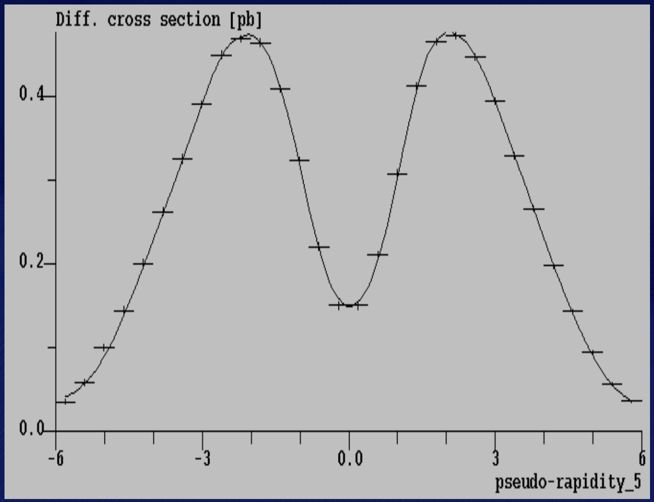
Pseudo-rapidity of top-quark



Wb-invariant mass



PT of b-quark



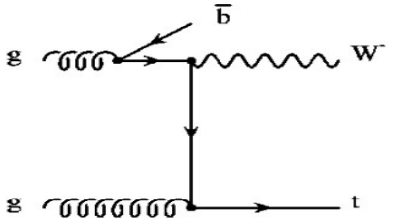
pseudo-rapidity of b-quark

σ = 3.2 pb

Treatment of the double counting: combining of the Wt+ISR and complete tWb processes (Matching 2→2 +ISR and 2→3 events).

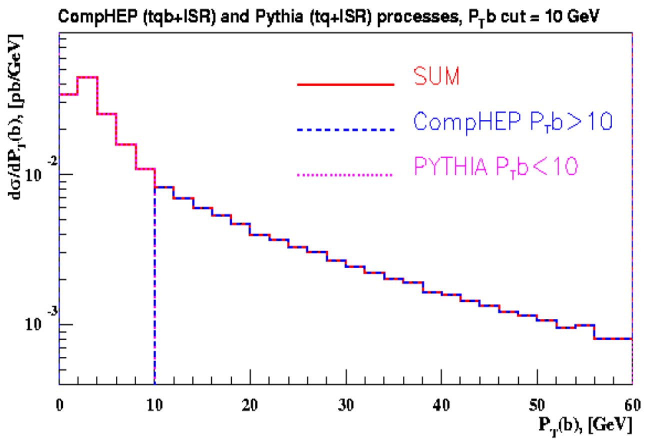
Monte-Carlo generator SingleTop (NLO approach).
(the same method as for t-channel NLO simulations)

(Boos, Bunichev, Dudko, Savrin, Sherstnev, Phys.Atom.Nucl.69 (2006) 1317)



MC Events with $P_T(b) > P_T^0$ *(hard region) modelled in the CompHEP.*
MC Events with $P_T(b) < P_T^0$ *(soft region) modelled with ISR simulation in the Pythia.*

Combining events from CompHEP at the Pythia level:



The relative contributions of the processes of the Pythia and CompHEP determined from the normalization conditions to the total NLO cross section

$$\sigma_{NLO} = K \cdot \sigma_{2\to 2+ISR} \big|_{P_T(b) < P_T^0} + \sigma_{2\to 3} \big|_{P_T(b) > P_T^0} .$$

P_T^0 -some value of the transverse momentum of additional b-quark
K-factor is chosen from the condition of smoothness of the distribution $P_T(b)$

Generator SingleTop correctly simulates the NLO correction.
No events with negative weights and there is no double counting of events

Concluding Remarks

- Developed a new algorithm for accurate modelling the single top tWb signal using CompHEP.
- First results of calculations is obtained.

Remains to be done

- Producing tWb events with anomalous couplings (in progress).
- Compare distributions from CompHEP-based generator SingleTop with other generators.